

EFFECT OF SIRE LINE AND REARING ENVIRONMENT ON THE GROWTH  
PERFORMANCE AND CARCASS CHARACTERISTICS OF GROWING-FINISHING PIGS

BY

NICHOLAS SCOTT GROHMANN

THESIS

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Adviser:

Professor Mike Ellis

## Abstract

The effects of sire line and rearing environment on the growth performance and carcass characteristics of growing-finishing pigs were evaluated using 208 barrows from 2 purebred sire lines. The study was conducted as a randomized complete block design (blocking factor was the day of start of test) with a 2 x 5 factorial arrangement of the following treatments: Sire line (Green vs. Blue) and Rearing Environment [ (Penning/feeding regime) 1) Individual pen (Building 1)/*Ad libitum*, 2) Individual pen (Building 1)/Restricted, 3) Individual pen (Building 2)/*Ad libitum*, 4) Individual pen (Building 2)/Restricted, and 5) Standard group pen (Building 2)/*Ad libitum*]. Pen was the experimental unit. This study was carried out from an initial live weight of  $38.4 \pm 1.78$  kg to two end points, namely to a fixed-weight of 122.5 kg mean pen live weight and to a fixed-time of 97 days on test (Week 14 of the study). For pigs on the restricted feeding treatment, the target restricted feeding level was 90% of the daily *ad libitum* feed intake of the standard group housed pigs (Trt. 5). The restricted feeding level was calculated within replicate. Throughout the study period the restricted fed pigs were fed twice per day at approximately 0700 and 1700 hours. Pigs were individually weighed at the start and end of the study period, and every two weeks until Week 12 of the study at which time they were weighed on a weekly basis until the end of the study. All feed additions and feed remaining in the feeder at the time of pig weighing were measured to determine feed intake and gain:feed ratio. At the end of Week 14, entire blocks were removed from test and transported to Cargill Meat Solutions (Beardstown, IL) for harvest. Pigs reared under restrict fed conditions had reduced average daily gain, daily feed intake and tenth rib backfat thickness as well as increased carcass lean content when compared to pigs reared under *ad libitum* fed conditions. The effect of restricted feeding on feed efficiency, however, was genotype dependent. For the Green sire line, there was no

effect of feeding regime on feed efficiency; however, feed efficiency was greater under restricted compared to *ad libitum* feeding for the Blue sire line. Under *ad libitum* fed conditions, barrows housed in groups of 8 pigs (Trt. 5) had similar growth performance and carcass characteristics to barrows that were penned individually (Trt. 1 and 3).

The presence of a treatment interaction in this study for feed efficiency, suggests that the two genotypes responded differently to changes in the environment, in this case feeding level, and highlights the importance that it is the combination of selection objectives and the environment in which pigs are tested in that create the differences between genotypes. Therefore, due to the unlimited combinations of genotypes and environments, the existence of G  $\times$  E interactions should be evaluated independently for each combination of genotypes and environments.

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## CHAPTER 1: Literature Review

### Genotype by Environment Interactions

The growth performance of pigs can be evaluated under many different environmental conditions such as individual housing versus group housing or ad libitum versus restricted access to feed and all of these can influence the overall performance of the animal. For this reason, research has been conducted to evaluate the performance and the variation in performance of growing and finishing pigs in various environments. In addition to environmental conditions another significant source of variation in overall performance is the genotype of the pig. When evaluating growth performance and carcass characteristics, there may be significant interactions between the genetic line and the environment in which it is tested that must be considered when trying to determine the best genotype to be used for a given situation. Interactions such as these are classified as genotype by environment ( $G \times E$ ) interactions.

*Definition.* As defined by Merks (1986) a  $G \times E$  interaction is a change in relative performance of two or more genotypes measured in two or more environments. According to James (2009), the relative changes in performance, or  $G \times E$  interactions, can be classified as either scale-type or rank-type interactions. James (2009) defined scale-type interactions as those in which the differences between genotypes change in magnitude, but not in sign, with changes in the environment. James (2009) also defined rank-type interactions as those in which one genotype may be superior to the other genotype in one environment, but the reverse is the case in the second environment. The distinction between these two types of interactions, therefore, has a significant impact when trying to determine superior genotypes, with rank-type interactions being of more practical importance.

In most cases in the literature, genotypes have represented as different breeds, groups of sires, or sires. Variation in growth performance as well as carcass characteristics among different genotypes of swine has been shown in many published studies (Gu et al., 1991; Friesen et al., 1994; Hasty et al., 2002; Hamilton et al., 2003). Differences among breeds are well documented, but variation in performance is also known to exist for lines selected within a particular breed. With such well documented variation in performance between differing genotypes tested in the same environment, the question then becomes, will different environments affect the performance of different genotypes to the same extent. Unlike genotype, environments have been less well defined and differences have often been represented by single specific environmental factors such as feeding level or stocking density, as well as entire testing environments such as test stations or commercial facilities that may include several factors that differ between environments.

*Effect of Genotype by Environment Interactions.* Historically, in the commercial swine industry, breeding animals have been evaluated and selected based on performance in test stations. It has been assumed that the genetic correlation between the same trait measured in different environments is close to one. Obviously, the progeny produced by these breeding animals are raised in commercial environments with the expectation that they will have similar relative performance to the test station performance of their parents. Merks (1986) stated that the concept of  $G \times E$  interaction is based on the idea that the expression of identical traits in different environments may not be controlled by the same sets of genes and, therefore, the expectation of high genetic correlation between performance traits measured in different environments may not always hold true. Test station environments may include housing accommodations such as individual penning or small groups of pigs with high levels of floor space, and changes in

feeding levels such as ad libitum or restricted, which are designed to increase the accuracy of measurements and meet selection or testing objectives. These environmental differences between the test station and commercial facilities can create the potential for a  $G \times E$  interaction between the performance of animals selected for breeding in test stations and the performance of progeny in commercial environments by allowing the expression of different genes that control the same phenotypic trait.

In a study by Merks (1986) the performance and carcass characteristics of pigs tested in a central test station and on a commercial farm were evaluated for any  $G \times E$  interactions between the two environments. Merks (1986) showed no significant  $G \times E$  interactions; however genotype by batch interactions were found for daily gain. Batch was defined as the individual group of pigs on test at a certain time, and Merks (1986) stated that differences in husbandry between the batches of pigs were the reason for the interaction. If husbandry is considered to be an environmental factor, such findings could be interpreted as a significant  $G \times E$  interaction. In another study, Merks (1989a) compared Dutch Landrace and Dutch Yorkshire pigs in three different environments that included central test station, on-farm test, and commercial fattening operation. This study showed significant  $G \times E$  interactions, however, the authors did not clearly define the differences between the testing environments. In another study, Merks (1989b) again showed significant  $G \times E$  interactions for all of the growth performance measures, and stated lower levels of control over feeding, housing, and disease as the specific environmental factors that differed between test station and commercial environments to cause the  $G \times E$  interactions. In another study, Schinckel et al. (1999) evaluated 288 pigs from two different genotypes. Sires from a European terminal cross sire line and sire from a Yorkshire-Landrace sire line were mated to females from a common dam line and progeny were raised in two different environments,

namely a segregated early weaning, three-stage production system or a conventional weaning, continuous flow two-stage grow-finish system. This study found significant  $G \times E$  interactions for average daily gain, feed intake, days to market, backfat thickness, carcass percent lean content, and death loss. Progeny of the European terminal cross sires had significantly higher death loss in the continuous flow environment than the progeny of the Yorkshire-Landrace sires, however, in the segregated early weaning environment there was no difference between the lines for death loss. Schinckel et al. (1999) conducted a second study, using three different sire lines with different potentials for lean growth (high, medium, and low) and evaluated them under the same two environments that were used in the first study. Schinckel et al. (1999) again showed  $G \times E$  interactions for average daily gain, feed efficiency, and morbidity. In the continuous flow environment the pigs with the lowest potential for lean growth had the highest feed intake, grew the fastest and required fewer days to reach market weight, however, there were no differences between the genotypes for feed efficiency. In the segregated early wean environment, there were no differences between the genotypes for average daily gain; however, the pigs with the highest potential for lean growth had the lowest feed intake and the highest feed efficiency. This suggests that the expression of feed intake in combination with the effect that the environment has on feed intake, may be one of the leading causes of  $G \times E$  interactions.

The studies by Merks (1986, 1989a, 1989b) and Schinckel et al. (1999) were designed to test for the possibility of  $G \times E$  interactions based on testing pigs in two entirely different testing environments. Obviously, there are numerous factors that can differ between such environments. Because of this, specific environmental factors could not be identified as the specific cause for any  $G \times E$  interactions that were found. Other studies, however, have evaluated different genotypes in environments that differed by only a single environmental



factor, such as stocking density, floor space, or feeding level. Minkema et al. (1970) evaluated 248 pigs from 10 different sires under either ad libitum or restrict feeding conditions and found no  $G \times E$  interactions for any of the growth performance measures or carcass characteristics. In another study, Swedish Yorkshire pigs were selected for lean tissue growth rate while being fed diets with low crude protein (13.1%) or high crude protein (18.5%) to form two separate selection lines (Johansen et al., 1993). After three generations of selection these two selected lines were tested for responses and interactions when fed three diets that contained 13.9, 15.8, or 17.5% crude protein. Johansen et al. (1993) showed no  $G \times E$  interactions for any of the traits tested, with the line selected on the 18.5% crude protein diet having superior performance across all dietary treatments. Bereskin et al. (1990) also conducted a study to evaluate  $G \times E$  interactions in lines selected for increased average daily gain and decreased backfat thickness on either high crude protein (24%) or low crude protein (12%) diets. After six generations of selection the two lines were tested on two diets that contained the same crude protein levels as used during the selection process. This study found a  $G \times E$  interaction for average daily gain and days to 91 kg. When the low protein diet was fed, pigs selected on the low crude protein diet grew faster and were younger when they reached 91 kg than the pigs selected on the high crude protein diet; however, when the high protein diet was fed the reverse was the case. This is one of the few rank-type  $G \times E$  interactions that has been reported in the literature. However, in this study there were no  $G \times E$  interactions for carcass measures (backfat thickness or *Longissimus* muscle area: Bereskin et al., 1990).

In another classic study, Fowler et al. (1960) evaluated 1705 animals for the presence of  $G \times E$  interactions between two genetic lines and two different feeding levels. The two genetic lines originated from a single population that had been randomly divided in half and assigned to

a selection program using either an ad libitum or restricted (~70% of ad libitum feed intake) feeding regime. Pigs were selected within each feeding level treatment for increased average daily gain for six generations. After six generations of selection, improvements in average daily gain had occurred in both lines. Subsequently, the two lines were tested on both feeding levels. This study showed that pigs selected on the restricted feeding level had superior performance over pigs selected on the ad libitum feeding level under both ad libitum and restricted feeding. Fowler et al. (1960) stated that selection for increased rate of gain under either ad libitum or restrict fed conditions resulted in the selection of two distinctly different genotypes. The increase in rate of gain in the pigs selected under ad libitum feeding conditions was due to the expression of higher feed intake, whereas the increase in rate of gain in the pigs selected under restrict feeding conditions was due to an increase in lean growth rate (Fowler et al., 1960). Under these restrict fed conditions variation in feed intake could not occur, therefore, the improvements in average daily gain were the result of changes in tissue composition. Because lean tissue growth requires less energy than fat tissue growth, it could be suggested that the pigs selected for increase rate of gain under restrict fed conditions, have a higher lean growth rate compared to those selection under ad libitum fed conditions (Cameron et al., 1994). This is a good example of how the response to selection for identical traits in different environments may not always be controlled by the same sets of genes, which was suggested by Merks (1986). The results of this study show the importance of the combination of both selection objectives and rearing environment in dictating the responses to any selection program. In this study, the deliberate restriction in feed intake resulted in selection of animals that had higher lean growth rates, and therefore, higher feed efficiency. Other environmental factors such as increased group sizes and reduced floor space may also cause reductions in feed intake that lead to  $G \times E$

interactions due to differences in lean growth rate potential and feed efficiency performance between the genotypes being tested. However, selection for increased daily gain in these environments may still result in an increase in feed intake, because variation in feed intake can still occur.

A study by Kuhlert et al. (1981) evaluated six different genotypes at two floor spaces (1.25 or 0.63 m<sup>2</sup>/pig), for the presence of  $G \times E$  interactions. Significant  $G \times E$  interactions were observed for average daily gain, backfat thickness, and lean tissue growth rate further demonstrating that not all genotype respond to changes in the environment in a similar manner. A study by Hamilton et al. (2003) evaluated 736 pigs from two genetic lines under both restricted and unrestricted floor space levels. The two lines being tested had different breed ancestry, but had been developed by the same breeding company. Hamilton et al. (2003) reported no  $G \times E$  interactions for any of the growth performance measures. Because the two genotypes were developed by the same breeding company, the results of this study suggest that genotypes developed using similar selection objectives and test environments may respond similarly to changes in the environment and be less likely to show  $G \times E$  interactions.

This review of the literature shows that a number of studies have been conducted to test for the existence of  $G \times E$  interactions in swine production. These studies have evaluated a range of genotypes in several types of environments. Some studies were designed to compare entire testing environments, such as test stations and commercial facilities, which may include several environmental factors that differ from one another, while other studies have evaluated different genotypes in the same general environment that was different only by a single environmental factor such as stocking density, floor space, or feeding level. These studies, however, have shown inconsistent results for the existence of  $G \times E$  interactions. Results from studies that

found  $G \times E$  interactions suggest that the genotypic control of the expression of feed intake in combination with the effect that the environment has on feed intake, may be one of the leading causes for  $G \times E$  interactions. Also, differences in the selection objectives and rearing environments used to develop the genotypes to be tested, may also be a leading contributor of  $G \times E$  interactions. This may suggest that genotypes developed using similar selection objectives and test environments may respond similarly to changes in the environment and be less likely to show  $G \times E$  interactions, however, due to limited research, uncertainty still remains. The lack of consistent results across studies suggests that the existence of  $G \times E$  interactions should be evaluated independently for each combination of genotypes and environments, due to the unlimited combinations of genotypes and environments.

### **Rearing Environment**

*Effect of Individual Housing versus Group Housing on Growth Performance.* There has been limited research that has evaluated how housing pigs either individually or in groups affects their overall growth performance. A study published by Tonn et al. (1985) looked at the growth performance of 31 Yorkshire boars from eight litters housed in either individual pens or in groups of 8 pigs from weaning (6 weeks of age) to 27 weeks of age (21-week study period). Littermate boars were allotted to one of four treatments: 1) Housed individually for the entire test period; 2) Housed in groups of 8 for the entire test period; 3) Housed individually for the first 6 weeks of the test and then in groups of 8 for the remaining 15 weeks of the test period; 4) Housed in groups of 8 for the first 6 weeks and individually for the remaining 15 weeks of the test period. Throughout the first 6 weeks of the study, pigs were housed in a confinement building where average temperatures were above 20 °C for the entire period. For the remaining 15 weeks of the study, pigs were housed in an open-fronted building during the cold weather

months of November to March. This study found that individually penned boars tended ( $P < 0.10$ ) to consume more feed and grow faster ( $P < 0.01$ ) than group penned boars from 6-12 weeks of age; however, the analyzed means were not reported. The effect on feed efficiency was also not reported. No differences in growth performance between any of the treatments were observed from 12-27 weeks of age. The variation in housing environments during the two different time periods of the study will have impacted the ambient temperature experienced by the pigs. When pigs were kept at the higher temperature, differences in growth performance were able to be detected between the treatments; however, this was not the case when pigs were challenged with colder temperatures. During cold weather, energy and nutrients that could have been used for growth may have been used instead to regulate body temperature, and the amount of energy needed to do so, may have been higher for the individually housed pigs, due to the lack of ability to huddle with other pigs to conserve energy. This may have impacted the results obtained, thus making them incomparable to pigs that would be housed in a total confinement system under thermo neutral conditions.

In another study, Patterson (1985) evaluated the growth performance and carcass characteristics of 120 growing/finishing boars and gilts housed either individually or in groups of five pigs per pen. The study was carried out from an initial live weight of 37.3 kg to an end live weight of 80.6 kg, using six replicates. Each replicate consisted of 10 boars and 10 gilts, with five pigs of each gender being housed individually and five being housed in a group. The experimental unit was the mean of five pigs. Daily feed allowance was adjusted after each weighing according to a scale based on metabolic live weight ( $100 \text{ g/kg LiveWeight}^{0.75}$ ) and was given in two equal amounts each day. All pigs were housed in the same building, which was maintained at a temperature of 21°C. At the end of the growth study pigs were harvested and

carcasses were evaluated. Similar to the results found by Tonn et al. (1985), this study showed that individually-housed pigs grew significantly faster ( $P < 0.01$ ) than the group-housed pigs, however, there was no difference between individual and group housing in feed efficiency. Although average daily feed intake data was not reported, because there was no difference in feed efficiency between the treatments, one can speculate that feed intake would be higher for the individually housed pigs to account for the increased daily weight gain. In addition, Patterson (1985) found that there was no difference between individual and group housed pigs for carcass yield, however, individually-housed pigs had significantly more fat ( $P < 0.05$ ) and less lean ( $P = 0.07$ ) in the carcass than the group-housed animals. Patterson (1985) suggested that the faster growth rate and greater fatness of the individually housed pigs indicated that these pigs were retaining considerably more energy as result of a lower metabolic heat production. Perhaps the most significant issue with Patterson's study would have to be his approach to feeding the pigs. As the amount of feed fed to each pig was based on live weight with weekly adjustments, any pig that grew faster initially, as the individually-housed pigs did, would receive more feed for the subsequent week. This approach may have increased the difference in performance between the individually-housed and group-housed pigs at each weekly weigh period and for the entire study period as a whole. The results of Patterson (1985) may not reflect what would be observed when pigs are given ad libitum access to feed as is typical of current commercial practice.

Another study that evaluated growing/finishing pigs housed either individually or in groups of five pigs per pen was published by Gonyou et al. (1992). In this study, 160 pigs (80 barrows and 80 gilts) with an initial live weight of 31 kg were housed in single-gender groups of eight pigs per pen for a week prior to the start of the actual study to ensure there was no effect of

initial mixing of pigs on the growth performance of the group-housed animals. After this initial period, three pigs were removed from each pen and moved to three individual pens adjacent to their original pen and the experiment was initiated. Pigs were individually weighed at the start and end of the study and every two weeks during a 10-week study period. Pigs were given ad libitum access to feed throughout the study period. Gonyou et al. (1992) reported that there was no difference in growth rate between the individually-housed and the group-housed pigs for any of the two week periods, but when compared over the entire study period individually-housed pigs tended ( $P < 0.10$ ) to gain 4% more than the group-housed pigs. Over the ten week study period individually housed pigs also consumed 5.5% more feed ( $P = 0.02$ ) than the groups housed pigs, however, there was no difference ( $P > 0.05$ ) in feed efficiency between the treatments. These results are similar to the results obtained by both Tonn et al. (1985) and Patterson (1985).

It has been suggested by Nielsen et al. (1996) that the increase in average daily feed intake and resulting increase in average daily gain when pigs are housed in individual pens may be due to an increase in the number of meals consumed each day. To test this hypothesis, Nielsen et al. (1996) evaluated 30 entire male pigs for 14 days using electronic feeding stations. At the end of the 14 days, 12 pigs from the original 30 pigs were selected to be housed individually for an additional 14 days. Pigs selected for further evaluation were selected based on the number of meals they ate throughout the day, with six pigs having a high (H) number of meals and six pigs having a low (L) number of meals. Nielsen et al. (1996) reported that when the pigs were housed in individual pens, the number of meals consumed per day was increased slightly compared to when they in group pens, but the increase was the same for both the H and L pigs. The small increase in meal frequency for both H and L pigs when they were individually-

housed, however, resulted in a significant ( $P < 0.05$ ) increase in average daily feed intake as well as average daily gain compared to when they were in the group pens. There was no difference ( $P > 0.05$ ) in average daily gain or average daily feed intake between the H and L pigs while they were individually housed. Although limited research has been conducted to evaluate how housing pigs either individually or in groups will affect their overall growth performance, the studies that have been carried out have generally shown similar results. Individually-housed pigs will generally grow faster, consume more feed, but have similar feed efficiency compared to pigs housed in small groups.

*Effect of Feeding Level on Growth Performance.* There has been limited research on the effect of ad libitum compared to restricted feeding on the growth performance of pigs throughout both the growing and finishing phases of production. Donker et al. (1986) carried out a study that evaluated 248 market pigs from an initial live weight of 22 kg to a fixed end weight of 105 kg. Pigs were housed in single gender pens of four pigs. Entire pens of pigs were allotted to one of the following four treatments: 1) *ad libitum* access to feed throughout both the growing and finishing phase; 2) *ad libitum* access during the growing phase and feeding time restricted to four hours each day during the finishing period; 3) feeding time restricted to four hours each day during the growing period and *ad libitum* access during the finishing period and 4) feeding time restricted to four hours each day during both the growing and finishing phases. Donker et al. (1986) showed that pigs given *ad libitum* access to feed throughout both the growing and finishing phases had similar overall average daily gain to pigs that were restricted only during the growing phase, however, pigs that were restricted only during the growing phase showed a 4.6% reduction in average daily feed intake when compared to pigs given *ad libitum* access to feed throughout both phases. In addition, compared to pigs given *ad libitum* access to feed



throughout both phases, average daily feed intake was reduced by 8.7% and 15.7% and average daily gain by 7.2% and 12.9% for pigs restricted only during the finishing phase and pigs restricted throughout both phases, respectively. However, there was no difference between the treatments for total feed consumed per pig over the test period, feed efficiency, or backfat thickness. The results of this study show that pigs restricted during the growing phase, can compensate for reduced growth rates during the time of restriction if allowed *ad libitum* access to feed during the finishing phase. These results also suggest that average daily gain is highly correlated with average daily feed intake, as shown by the lack of a difference in feed efficiency between the treatments.

In the study of Donker et al. (1986), described above, the restriction of feed intake was achieved by limiting the amount of time pigs were allowed access to feed. In other studies the restriction has been achieved by limiting the amount of feed offered to the pigs each day. Using this approach allows for more control over the amount of feed that a pig is allowed to consume on a daily basis. One study that used this approach (Ramaekers, 1996) evaluated 72 barrows from an initial live weight of 29 kg to a fixed end live weight of 105 kg. Pigs were housed in groups of 12 and feed was made available through an electronic feeding station that was capable of recording feed intake for each individual pig within the pen. Pigs were allotted on the basis of live weight and litter to one of the following three treatments: 1) *ad libitum* access to a high energy diet (13.1 MJ/kg ME), 2) restricted to a daily energy allowance of 18 MJ ME above maintenance requirement, based on metabolic live weight with a high energy diet (13.1 MJ/kg ME), 3) restricted to a daily energy allowance of 18 MJ ME above maintenance requirement, based on metabolic live weight with a low energy diet (12.5 MJ/kg ME). For the first 36 days of the study all pigs were given *ad libitum* access to the same diet (12.7 MJ/kg ME); for the

remainder of the study pigs were fed according to their allotted treatment. Pigs were harvested at the end of the study and carcasses were evaluated for lean and fat content. The results of this study showed that there was no difference in growth performance or carcass characteristics between the two restrict fed treatments. When the restrict fed pigs were compared to the *ad libitum* fed pigs there was no difference in feed efficiency, however, average daily gain was 20.3% lower, and the percentage of lean and fat tissue in the carcass were 2.6% higher and 2.1% lower, respectively, for the restrict fed pigs.

Another study that limited the amount of feed offered to the pig each day was that of Reinhart (1989) that evaluated 28 pigs in 4 replicates in a randomized complete block design for a fixed time of four weeks. Pigs were allotted at weaning (~5.9 kg) by weight and litter to one of the following three treatments: 1) individually-housed and pair-fed 90% of the daily feed intake of pigs on Treatment 3, 2) housed in pens of 3 pigs and pair-fed 90% of the daily feed intake of pigs on Treatment 3, 3) housed in pens of 3 pigs and allowed *ad libitum* access to feed. Although, this study was carried out only during part of the growing phase, the results were similar to the two grow to finish studies previously discussed (Donker, 1986; Ramaekers, 1996). The restricted fed pigs grew 14.6% slower and consumed 19.0% less feed compared to the pigs that were given *ad libitum* access to feed, however, there was no difference in feed efficiency.

The three studies previously discussed all had similar results and showed that when restrict fed pigs are compared with pigs that have *ad libitum* access to feed, they grow slower, eat less feed and are leaner, yet have similar feed efficiency. A study conducted by Leymaster et al. (1991) showed different results, however, with regards to feed efficiency. Leymaster et al. (1991) evaluated 36 barrows, with an initial live weight of 37.8 kg, over a fixed time of 84 days. Littermate barrows were allotted by weight to one of three treatments: 1) *ad libitum* feed intake,

2) 92.5% of feed intake of Treatment 1, or 3) 85% of feed intake of Treatment 1. Following the 84 day study period all pigs were sent for harvest and carcasses were evaluated for water, protein, ether extract, and ash content. Results showed that average daily gain tended ( $P = 0.06$ ) to decrease with increasing level of restriction, with pigs restricted at 92.5% and 85% of *ad libitum* intake growing 3.7% and 7.4% slower, respectively, compared to the *ad libitum* fed pigs. However, unlike the studies previously discussed (Donker, 1986; Reinhart, 1989; Ramaekers, 1996), the results of this study showed that there was a significant difference ( $P < 0.05$ ) in feed efficiency between the treatments. The pigs restricted at 85% of *ad libitum* intake were 8.4% more ( $P = 0.02$ ) efficient than the *ad libitum* fed pigs, and, although not significantly different than either of the other two treatments, the pigs restricted at 92.5% of *ad libitum* intake did have a feed efficiency that was intermediate between that of the other two treatments. Similarly, the pigs restricted at 85% of *ad libitum* intake showed a decrease ( $P < 0.05$ ) of 11.7% in backfat depth compared to the *ad libitum* fed pigs, with the pigs restricted at 92.5% of *ad libitum* intake again being intermediate but not statistically different for backfat depth. Evaluation of the carcasses revealed no difference ( $P > 0.05$ ) between the treatments for water, protein and ash content, however, there was a 17.9% and 10.5% reduction ( $P < 0.05$ ) in ether extract content in the carcasses of the pigs restricted at 85% and 92.5% of *ad libitum* intake, respectively, compared to the *ad libitum* fed pigs. These results show similar effects for average daily gain and carcass leanness when compared to the studies previously discussed (Donker, 1986; Reinhart, 1989; Ramaekers, 1996), however, they also suggest that restriction of feed intake to 85% and 92.5% of *ad libitum* intake will increase feed efficiency when compared to pigs given *ad libitum* access to feed.

Although the number of studies evaluating the specific effects of restricted compared to *ad libitum* feeding levels is limited, the effects on average daily gain, average daily feed intake, as well as carcass leanness are consistent across all studies. These studies have shown that restrict fed pigs will grow slower, consume less feed and have leaner carcasses when compared to pigs that have had *ad libitum* access to feed. The effect that restricted feeding has on feed efficiency is still unclear, however, as some studies have shown no effect, while others have shown an increase in feed efficiency. Differences between the studies for the effect of restricting feed on feed efficiency may be due to differences in the genotypes used in each study. Further investigation of the effect of restricted feeding on feed efficiency is, therefore, warranted due to its high economic importance for swine producers.

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## **CHAPTER 2: Effect of Sire Line and Rearing Environment on the Growth Performance and Carcass Characteristics of Growing-Finishing Pigs.**

### **Introduction**

There is considerable variation between commercial genetic lines in terms of physical and economic performance levels (Gu et al., 1991; Friesen et al., 1994; Hasty et al., 2002; Hamilton et al., 2003). The differences in performance are often the result of different selection objectives and testing environments used to develop each particular genotype, ultimately resulting in the expression of different genes (Webb, 1986). Because of this variation in performance, the choice of genetic line is one of the most critical for producers as this will determine the ultimate profitability of the production enterprise. This choice is often based on results of genetic line comparisons that can be carried out under a variety of environmental conditions such as individual housing versus group housing or ad libitum versus restricted access to feed, which can all influence the overall performance of the animal, and, potentially, the differences in performance between different genetic lines.

When evaluating growth performance and carcass characteristics, there may be significant interactions between the genetic line and the environment it is reared under that must be considered when trying to determine the best environment to test for genetic differences. Interactions such as these are classified as genotype by environment ( $G \times E$ ) interactions. As defined by Merks (1986) a  $G \times E$  interaction is a change in relative performance of two or more genotypes measured in two or more environments. A number of studies have been conducted to test for the existence of  $G \times E$  interactions in swine production. In these studies, large variations

in the genotypes tested and also in the range of environments evaluated have, however, resulted in inconsistent results for the existence of  $G \times E$  interactions. Results from studies that found  $G \times E$  interactions suggest that the genotypic control of the expression of feed intake in combination with the effect that the environment has on feed intake, may be one of the leading causes for  $G \times E$  interactions. Also, differences in the selection objectives and test environments used to develop the genotypes to be tested, may also be a leading contributor to  $G \times E$  interactions. This may suggest that genotypes developed using similar selection objectives and test environments may respond similarly to changes in the environment and be less likely to show  $G \times E$  interactions, however, due to limited research, uncertainty still remains. The lack of consistent results across studies suggests that the existence of  $G \times E$  interactions should be evaluated independently for each combination of genotypes and environments, due to the unlimited combinations of genotypes and environments.

Therefore, the objectives of this research were to: 1) compare two commercial sire lines based on barrow progeny growth performance and carcass characteristics and, 2) evaluate the relationship between feed intake, feed efficiency, and live animal and carcass growth of growing-finishing pigs housed individually or in groups, and fed at different levels, namely, ad libitum or restricted.

## **Materials and Methods**

This study was conducted at the University of Illinois's Grein Farm (in Isolation Buildings 1 and 2), which is located in Savoy, IL 61874 USA. The experimental protocol was approved by the University of Illinois Institutional Animal Care and Use Committee (IACUC #10241).



*Facilities.* This study was carried out in two different buildings located approximately 40 meters apart. Building 1 was an individual pig housing facility that consisted of two identical rooms with fully slotted plastic flooring and pen divisions and gates consisting of vertical steel rods. Each room was 18.0 m long and 4.6 m wide with 2.1 m high ceilings and a central aisle (0.6 m wide). There were 36 pens in each room (32 were used in the study). Pen dimensions were 1.0 m x 2.0 m, providing a total available floor space allowance (total area minus space taken by the feeder) of 1.95 m<sup>2</sup> per pig. Room temperatures were independently regulated in each room by thermostatically controlled exhaust fans and a heater suspended in each room. The room temperature was set at 24° C at the start of the study and gradually lowered over the course of 9 weeks until it reached 18° C where it was held for the duration of the study period. Pigs were given access to feed via a single space stainless steel dry box feeder in each pen and water was freely available via a cup drinker in each pen mounted on the pen partition.

Building 2 was a mechanically ventilated wean-to-finish facility consisting of four rooms, each with fully slotted concrete flooring and pen divisions and gates consisting of vertical steel rods. Each room was 7.32 m long and 8.23 m wide with 2.1 m high ceilings. Rooms 1, 3 and 4 were used in this study and each had six standard group pens measuring 1.83 m x 3.66 m and 6 individual pens measuring 1.83 m x 1.22 m providing a total available floor space (total area minus space taken by the feeder) of 0.80m<sup>2</sup> and 2.14 m<sup>2</sup> per pig, respectively. Room temperatures were independently regulated in each room by thermostatically controlled exhaust fans and a heater suspended in each room. The individually housed pigs were given access to feed via a single space stainless steel dry box feeder and water was freely available via a cup drinker mounted on the pen partition. Pigs in the standard group pens were given ad libitum

access to feed via a 2-space stainless steel dry box feeder and water was freely available via a cup drinker mounted on the pen partition.

*Experimental Design and Treatments.* The study was conducted as a randomized complete block design (blocking factor was the day of start of test) with a  $2 \times 5$  factorial arrangement of the following treatments:

- A. Sire line: 1) Green; 2) Blue. The pigs used in the study were from two purebred sire lines and were all barrows. Pen was the experimental unit.
- B. Rearing Environment (Penning/feeding regime): 1) Individual pen (Building 1)/*Ad libitum*; 2) Individual pen (Building 1)/Restricted; 3) Individual pen (Building 2)/*Ad libitum*; 4) Individual pen (Building 2)/Restricted; 5) Standard group pen (Building 2)/*Ad libitum*

*Animals and Pre-test Management.* The two sire lines were selected for the study based on historical data from the producer that supplied the animals that suggested the Blue line had a higher feed intake, was faster growing, and fatter than the Green line. The Green line pigs were of Landrace ancestry and came from a total of 54 litters produced by 19 sires. The Blue line pigs were of Yorkshire ancestry and came from a total of 52 litters produced by 15 sires.

Between weeks 7 and 8 post-weaning, at approximately 25 kg live weight, the pigs were transported to the University of Illinois using a standard livestock trailer. Upon arrival pigs were individually tagged and placed into single-genotype pens of 18 pigs. They were allowed a 2-week acclimation period during which they were housed in rooms 3 and 4 of Building 2. The room temperature was set at 24° C for the duration of the acclimation period. Pigs were offered *ad libitum* access to feed via a two-hole dry box feeder, and water was freely available via a cup drinker. Diets were formulated using corn, dried distillers grains with solubles (DDGS), and

soybean meal and to meet or exceed NRC (1998) recommendations for nutrient requirements for pigs across the weight range used.

*Allotment.* Allotment was carried out within sire line and was based on individual pig weights. At the conclusion of the 2-week acclimation period all pigs were individually weighed and the heaviest 52 pigs (~38 kg mean live weight) from each sire line were selected for allotment to Block 1 (Replicates 1 and 2). The objective was at the start of test for all pens (individual pigs and groups) to have a similar mean pen weight, and for the group pens to have a similar variation in weight. Within sire line the selected 52 pigs were ranked by weight and split into 8 weight categories with 4, 4, 4, 14, 14, 4, 4 and 4 pigs in each weight category, respectively. Within sire line, a replicate consisted of 12 pens (2 standard group pens with 8 pigs, and 10 individual pens with 1 pig). One pig from each of the 8 weight categories was randomly allotted to each of the group pens. This process was repeated until there were 8 pigs in each of the group pens. Following allotment of the group pens, the 10 remaining pigs (which were from the middle two weight categories) were randomly allotted to the individual pens with 8 pens in Building 1 and 2 pens in Building 2. The mean pen weights and variation in weight (for the group pens) were checked and pigs were moved between pens to equalize these. Within each allotment, pigs in the individual pens were randomly allotted to feeding regime treatment. This process was repeated for the second sire line. Once pigs were allotted they were moved to their respective pens. Pigs on Treatments 1 and 2 were moved to Building 1 and pigs on Treatments 3 to 5 remained in Building 2, where they were housed for the duration of the growth performance study. Block 2 (Replicates 3 and 4) was allotted two weeks later using the heaviest 52 pigs from each sire line from the remaining population of pigs and the same allotment procedures were used as for Block 1.

*Test Period.* This study was carried out from an initial live weight of  $38.4 \pm 1.78$  kg to two end points, namely to a fixed-weight of 122.5 kg mean pen live weight and to a fixed-time of 97 days on test (Week 14 of the study). At the end of Week 14, entire blocks were removed from test and transported to Cargill Meat Solutions (Beardstown, IL) for harvest. Pigs were held in lairage overnight at the plant with access to water but not feed and were harvested the following morning according to standard procedures.

*Restricted Feeding Level.* The target restricted feeding level was 90% of the daily *ad libitum* feed intake of the standard group housed pigs (Trt. 5). The restricted feeding level was calculated within replicate. For all groups of pigs on Trt. 5, the average daily feed intake for each two week period was regressed against the mean pen live weight for each period (i.e. the mean of the weights taken at the start and the end of the period). For the restricted fed pigs (Trts. 2 and 4), live weight was predicted for the mid-point of each subsequent 2-week period based on the average growth rate of all restricted fed pigs within a replicate during the preceding 2-week period. The restricted feeding level was calculated as 90% of the daily *ad libitum* feed intake of Trt. 5, based on the regression from Trt. 5 and the predicted mid-point live weight for all restricted fed pigs within a replicate. Throughout the study period the restricted fed pigs were fed twice per day at approximately 0700 and 1700 hours.

*Measurements.* Pigs were individually weighed at the start and end of the study period, and every two weeks until Week 12 of the study at which time they were weighed on a weekly basis until the end of the study. All feed additions and feed remaining in the feeder at the time of pig weighing were measured to determine feed intake and gain:feed ratio. Beginning at ~60 kg live weight, all pigs were ultrasonically scanned at the time of pig weighing using an Aloka Model 500V B-mode ultrasound scanner fitted with an Aloka 5011 probe (Corometrics Medical

Systems, Wallingford, CT). A transverse image was taken over the tenth rib and back fat thickness (over the middle of the *Longissimus* muscle) and *Longissimus* muscle area were measured on the image.

*Harvest and Carcass Measures.* Carcass measurements were taken on the slaughter line after harvest immediately prior to entering the chiller. Hot carcass weight and Fat-o-Meater measurements that included backfat, *Longissimus* muscle depth at the 10<sup>th</sup> rib and a predicted carcass percent lean were measured for each carcass.

*Statistical Analysis.* All data were tested for normality using the PROC UNIVARIATE procedure of SAS (SAS Inst. Inc., Cary, NC). The pen was the experimental unit for both the growth study and for the carcass measurements. Morbidity and mortality data, which were not normally distributed, was analyzed using a Chi-square rank-based test (Steel and Torrie, 1980) using the PROC RANKS procedure of SAS. Data meeting the criteria for normality were analyzed using the PROC MIXED procedure of SAS. Data were analyzed as a randomized complete block design with the model used accounting for the fixed effects of sire line and test environment and the two-way interaction, and the random effect of block and replicate. Least-squares means were compared using the PDIFF option of SAS.

## **Results and Discussion**

*Effect of sire line.* The results for the main effect of sire line on growth performance to a fixed weight and its effect on growth performance and carcass characteristics over a fixed time are presented in Table 1. This study was carried out to a fixed end live weight of 122.5 kg as well as over a fixed time of 97 days. There were no differences ( $P > 0.05$ ) in growth performance or carcass characteristics between the two sire lines when compared on either a fixed weight or a

fixed time basis. There was a difference ( $P < 0.05$ ) between the two sire lines for the coefficient of variation of live weight at the start of the test which was greater for the Blue than the Green sire line (11.9 and 10.9, respectively; Table 1). However, this difference was most likely due to chance sampling; there was no effect ( $P > 0.05$ ) of sire line on the coefficient of variation for live weight at the end of test. The growth performance results obtained in this study are in contrast to the historical data from the source farm which suggested that the Blue sire line pigs had a higher feed intake, grew faster, and were fatter than the Green sire line pigs.

Although there were no differences in growth performance between the two sire lines, there was a significant sire line by rearing environment treatment interaction for overall feed efficiency at a common end live weight as well as for the total amount of feed needed per pig to reach the target end live weight (Tables 2 and 3). For the Blue line, feed efficiency was greater for pigs in the two restricted-fed treatments (Trt. 2 and 4) compared to the three ad libitum-fed treatments. However, for the Green line the only statistically significant ( $P < 0.05$ ) difference between the test environment treatments was for the restricted-fed pigs in Building 1 (Trt. 2) which had a greater feed efficiency than the group/ad libitum-fed pigs in Building 2 (Trt. 5). There was also a significant sire line by rearing environment interaction for the total amount of feed needed per pig to reach the target end live weight of 122.5 kg. The results of this interaction were in line with the results of the live weight feed efficiency and showed that when Green line pigs were compared within the same building, feeding level treatment had no significant impact on the total amount of feed needed per pig to reach the target end live weight. When Blue sire line pigs were compared, however, ad libitum fed pigs [either housed individually (Trt. 1 and 3) or in groups (Trt. 5)], consumed significantly more feed than the individually housed restrict fed pigs to reach the same target end live weight.

*Ad libitum and restricted feeding levels.* The results for the overall feed intake levels for all treatments are presented in Table 3. The actual restricted feeding level was 82.3% of the ad libitum intake of the group housed/ ad libitum fed pigs (Trt. 5). Pigs on the restrict fed treatments were restricted daily by 82.3% during the fixed weight test period and by 80.6% during the fixed time test period. Therefore, the target restricted feeding level of 90% of the daily ad libitum feed intake of the Trt. 5 was not achieved. This discrepancy in daily feed restriction was due to an under estimation of the ad libitum feed intake at the beginning of the study and subsequent inaccurate calculations of 90% of the daily ad libitum feed intake of the group housed/ ad libitum fed pigs. Despite this discrepancy, however, all restricted-fed pigs within a replicate were fed the same amount of feed throughout each period of the study and although the target restriction level of 90% was not achieved, the objective of comparing all restricted-fed pigs at a common feed intake level was met.

*Effect of rearing environment.* The results for the effect of rearing environment on growth performance to a fixed weight and its effect on growth performance and carcass characteristics over a fixed time are presented in Tables 4 and 5. As previously mentioned, this study was terminated at both a fixed time (97 days) and a fixed weight (122.5 kg). With the exception of live weight, which as expected was greater for the *ad libitum*-fed pigs than the restricted-fed pigs after the fixed-time comparison, differences in growth performance between the rearing environments were similar for the two end points. As expected, restrict fed pigs grew slower than those given *ad libitum* access. When compared to the group housed /*ad libitum*-fed pigs, the two individually-housed/ restricted-fed treatments had an approximate 11.3% and 15.1% reduction in average daily live weight gain, respectively. This reduction in gain resulted in the restricted-fed pigs being lighter at day 97 of the study and requiring more days on test (10.7 more

days and 14.4 more days,  $P < 0.05$ , for Trt. 2 and 4, respectively) to reach the target end weight of 122.5 kg when compared to the group housed /*ad libitum*-fed pigs. These results are in line with Donker et al. (1986), Reinhart et al. (1989), Leymaster et al. (1991), and Ramaekers et al. (1996) which showed reductions in average daily gain that ranged from 3.7 to 20.3% when restrict fed pigs were compared to pigs that were given *ad libitum* access to feed. By study design, average daily feed intake was higher ( $P < 0.05$ ) for *ad libitum*-fed pigs, both group and individually housed, than for the restricted-fed pigs. There was no difference ( $P > 0.05$ ) between the group housed/ *ad libitum*-fed pigs and the individually-housed, *ad libitum*-fed pigs, which is in contrast to the results reported by Tonn et al. (1985), Patterson (1985), and Gonyou (1992) that showed individually-housed pigs consumed significantly more feed. There was a difference ( $P < 0.05$ ) between rearing environment treatments for live weight feed efficiency when pigs were taken to a fixed weight of 122.5 kg, with the restricted-fed pigs in Building 1 being more efficient, statistically, than pigs on all the other treatments and the restricted fed pigs in Building 2 showing a numerically higher feed efficiency compared to the remaining *ad libitum* fed treatments (Trt. 1, 3, and 5). Similar results for live weight feed efficiency were seen for both end points of the study (Tables 4 and 5).

At harvest, *ad libitum*-fed pigs had heavier live body weights and greater hot carcass weights and carcass yields than the restricted-fed pigs. The difference in live body weight and hot carcass weight were as expected and the differences in yield can be attributed, in part at least, to the relatively large differences in harvest live weight between the treatments. Fat-O-Meater measurements collected at the 10<sup>th</sup> rib showed no difference ( $P > 0.05$ ) between the treatments for *Longissimus* muscle depth, but there was a difference ( $P < 0.05$ ) for back fat depth and predicted carcass lean content. When compared to group housed/*ad libitum*-fed pigs (Trt. 5)



individually-housed/ restricted-fed pigs (Trt. 2 and 4) had 20.2% and 23.1% less backfat and 1.9% and 2.0% higher predicted carcass lean content.

These results suggest that when testing for different traits, certain environments may be better than others for detecting differences between genotypes. The presence of a treatment interaction in this study for feed efficiency, suggests that the two genotypes responded differently to changes in the environment, in this case feeding level. Because feed intake was equivalent for both genotypes in the restrict fed treatments, the increase in feed efficiency for the Blue sire line pigs was due to an increase in average daily gain, and because lean tissue growth requires less energy than fat tissue growth, it could be suggested that the Blue sire line pigs have a higher lean growth rate compared to the Green sire line pigs (Cameron et al., 1994). For a commercial producer looking to implement a restricted feeding program, this information would be of vital importance and would not have been revealed had the two genotypes been tested under *ad libitum* feeding conditions. In fact, had the two genotypes been reared under only individually-housed/ *ad libitum* fed conditions, the numerically greater feed efficiency of the Green sire line pigs would have identified them as the superior genotype. This reduction in feed efficiency for Blue sire line pigs under individually-housed/*ad libitum* fed conditions, may suggest that under these conditions Blue sire line pigs show a higher degree of feed wastage, perhaps due to eating behavior. This was not tested in this study; however, it further illustrates the potential for  $G \times E$  interactions that may exist between differing genotypes.

This study shows that differences in rearing environments can lead to variation in growth performance and carcass characteristics. When genetic selection is considered, this highlights the point that it is the combination of selection objectives and the environment in which pigs are tested in that create the differences in the genetic potential for growth between genotypes. It

may be hypothesized that genotypes developed using similar selection objectives and rearing environments may respond similarly to changes in the environment and be less likely to show  $G \times E$  interactions, however, due to limited research, uncertainty still remains.

## Conclusions

The results of this study show that the environment in which pigs are reared, in particular differences in feeding level, can significantly alter overall growth performance of growing-finishing pigs. Pigs reared under restrict fed conditions had reduced average daily gain, daily feed intake and tenth rib backfat thickness as well as an increase in predicted carcass lean percentage when compared to pigs reared under *ad libitum* fed conditions. The effect of restricted feeding on feed efficiency, however, was genotype dependent and resulted in an improvement in feed efficiency for Blue sire line pigs, but no effect for Green sire line pigs. Under *ad libitum* fed conditions, the barrows housed in small groups of 8 pigs, had similar growth performance and carcass characteristics to barrows that were penned individually. The presence of a treatment interaction in this study for feed efficiency to a fixed weight, suggests that the two genotypes responded differently to changes in the environment, in this case feeding level, and highlights the importance that when it come to genetic selection, it is the combination of selection objectives and the environment in which pigs are reared in that create the differences between genotypes. Therefore, due to the unlimited combinations of genotypes and environments, the existence of  $G \times E$  interactions should be evaluated independently for each combination of genotypes and environments.

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## Tables

**Table 1.** Effect of sire line on growth performance evaluated over either a fixed-weight or fixed-time period.

| Treatment   | Sire Line (SL)    |                   | SEM    | P-value |
|---|-------------------|-------------------|--------|---------|
| Item  | Green             | Blue              |        |         |
| Number of pens                                    | 48                | 48                |        |         |
| <b><u>Growth performance</u></b>                  |                   |                   |        |         |
| Body weight, kg:                                  |                   |                   |        |         |
| Start of test                                     | 38.7              | 38.0              | 0.71   | 0.08    |
| End of test                                       |                   |                   |        |         |
| Fixed Weight (122.5 kg)                           | 123.4             | 123.1             | 0.54   | 0.72    |
| Fixed Time  | 130.0             | 131.1             | 1.19   | 0.43    |
| Coefficient of variation (within-pen), %:         |                   |                   |        |         |
| Start of test                                     | 10.9 <sup>b</sup> | 11.9 <sup>a</sup> | 0.81   | 0.02    |
| End of test                                       |                   |                   |        |         |
| Fixed Weight (122.5 kg)                           | 6.9               | 6.6               | 0.56   | 0.77    |
| Fixed Time  | 6.8               | 6.3               | 0.67   | 0.59    |
| Days on test                                      |                   |                   |        |         |
| Fixed Weight (122.5kg) <sup>1</sup>               | 89.6              | 88.6              | 1.2    | 0.33    |
| Fixed Time  | 97                | 97                | -      | -       |
| Overall growth performance:                       |                   |                   |        |         |
| Average daily live weight gain, g                 |                   |                   |        |         |
| Fixed Weight, (122.5 kg) <sup>1</sup>             | 957               | 971               | 15.0   | 0.29    |
| Fixed Time  | 943               | 961               | 18.1   | 0.29    |
| Average daily feed intake, kg                     |                   |                   |        |         |
| Fixed Weight (122.5 kg) <sup>1</sup>              | 2.63              | 2.68              | 0.036  | 0.13    |
| Fixed Time  | 2.67              | 2.73              | 0.040  | 0.13    |
| Gain:feed, kg:kg                                  |                   |                   |        |         |
| Fixed Weight (122.5 kg) <sup>1</sup>              | 0.365             | 0.363             | 0.0032 | 0.82    |
| Fixed Time  | 0.355             | 0.354             | 0.0031 | 0.81    |
| Morbidity and mortality, %                        | 2.24              | 0.00              | -      | 0.08    |
| <b><u>Carcass characteristics<sup>2</sup></u></b> |                   |                   |        |         |
| Harvest live weight, kg                           | 131.7             | 133.6             | 1.04   | 0.22    |
| Hot carcass weight, kg                            | 99.8              | 101.0             | 0.76   | 0.29    |
| Carcass yield, %                                  | 75.7              | 75.5              | 0.31   | 0.43    |
| Fat-O-Meater measurements (10 <sup>th</sup> rib): |                   |                   |        |         |
| <i>Longissimus</i> muscle depth, cm               | 6.05              | 6.07              | 0.107  | 0.91    |
| Backfat depth, cm                                 | 2.49              | 2.41              | 0.061  | 0.52    |
| Predicted carcass lean content, %                 | 50.7              | 50.9              | 0.28   | 0.59    |

<sup>a,b,c,d,e</sup>Means within a row or interaction subclass with different superscripts differ ( $P < 0.05$ ).

<sup>1</sup>Means were corrected to a common fixed end of test weight of 123.2 kg.

<sup>2</sup> Measured on all pigs that completed the growth study.

**Table 2.** Least squares means for the effect of sire line and rearing environment and the interaction on live weight feed efficiency to a fixed weight.

| Treatment                                   | Sire Line (SL) |       |        |         | Rearing Environment (RE) |                     |                      |                      |                     |        | P-value |                     |
|---|----------------|-------|--------|---------|--------------------------|---------------------|----------------------|----------------------|---------------------|--------|---------|---------------------|
| Item  | Green          | Blue  | SEM    | P-value | (1) <sup>2</sup>         | (2) <sup>3</sup>    | (3) <sup>4</sup>     | (4) <sup>5</sup>     | (5) <sup>6</sup>    | SEM    | P-value | SL x RE Interaction |
| Number of pens                              | 48             | 48    |        |         | 32                       | 32                  | 8                    | 8                    | 16                  |        |         |                     |
| Gain:feed (live weight), kg:kg <sup>1</sup> | 0.365          | 0.363 | 0.0032 | 0.82    | 0.365 <sup>b</sup>       | 0.382 <sup>a</sup>  | 0.351 <sup>b</sup>   | 0.367 <sup>b</sup>   | 0.355 <sup>b</sup>  | 0.0050 | <0.001  | 0.02                |
| Sire Line                                   |                |       |        |         |                          |                     |                      |                      |                     |        |         |                     |
| Green                                       | -              | -     | -      | -       | 0.371 <sup>bc</sup>      | 0.377 <sup>ab</sup> | 0.363 <sup>bcd</sup> | 0.356 <sup>bcd</sup> | 0.356 <sup>cd</sup> | 0.0069 | -       | -                   |
| Blue  | -              | -     | -      | -       | 0.359 <sup>cd</sup>      | 0.388 <sup>a</sup>  | 0.339 <sup>d</sup>   | 0.377 <sup>abc</sup> | 0.354 <sup>d</sup>  | -      | -       | -                   |

<sup>a,b,c,d,e</sup> Means within a row or interaction subclass with different superscripts differ ( $P < 0.05$ ).

<sup>1</sup> Means were corrected to a common fixed end of test weight of 123.2 kg.

<sup>2</sup> Individual pen (Building 1)/*Ad libitum*

<sup>3</sup> Individual pen (Building 1)/Restricted

<sup>4</sup> Individual pen (Building 2)/*Ad libitum*

<sup>5</sup> Individual pen (Building 2)/Restricted

<sup>6</sup> Standard group pen (Building 2)/*Ad libitum*

**Table 3.** Least squares means for the effect of sire line and rearing environment and the interaction on total feed consumption.

| Treatment                                | Sire Line (SL) |        | Rearing Environment (RE) |                 |                      |                      |                       |                        |                      | <i>P</i> -value |                 |                     |
|--|----------------|--------|--------------------------|-----------------|----------------------|----------------------|-----------------------|------------------------|----------------------|-----------------|-----------------|---------------------|
| Item                                     | Green          | Blue   | SEM                      | <i>P</i> -value | (1) <sup>2</sup>     | (2) <sup>3</sup>     | (3) <sup>4</sup>      | (4) <sup>5</sup>       | (5) <sup>6</sup>     | SEM             | <i>P</i> -value | SL x RE Interaction |
| Number of pens                           | 48             | 48     |                          |                 | 32                   | 32                   | 8                     | 8                      | 16                   |                 |                 |                     |
| Fixed Weight (122.5 kg)                  |                |        |                          |                 |                      |                      |                       |                        |                      |                 |                 |                     |
| Total feed Consumed/pig, kg <sup>1</sup> | 233.16         | 235.17 | 2.723                    | 0.48            | 232.83 <sup>b</sup>  | 222.28 <sup>c</sup>  | 243.16 <sup>a</sup>   | 231.86 <sup>ab</sup>   | 240.68 <sup>a</sup>  | 3.67            | <0.001          | 0.02                |
| Sire Line                                |                |        |                          |                 |                      |                      |                       |                        |                      |                 |                 |                     |
| Green                                    | -              | -      | -                        | -               | 227.99 <sup>de</sup> | 224.91 <sup>de</sup> | 234.71 <sup>bcd</sup> | 237.51 <sup>abcd</sup> | 240.66 <sup>ab</sup> | 5.133           | -               | -                   |
| Blue                                     | -              | -      | -                        | -               | 237.67 <sup>bc</sup> | 219.64 <sup>c</sup>  | 251.62 <sup>a</sup>   | 226.21 <sup>cde</sup>  | 240.69 <sup>ab</sup> | -               | -               | -                   |
| Start to Day 97 (fixed time)             |                |        |                          |                 |                      |                      |                       |                        |                      |                 |                 |                     |
| Total feed Consumed/pig, kg              | 258.63         | 264.2  | 3.904                    | 0.13            | 279.9 <sup>b</sup>   | 225.98 <sup>c</sup>  | 295.03 <sup>a</sup>   | 225.61 <sup>c</sup>    | 280.55 <sup>b</sup>  | 4.949           | <0.001          | 0.67                |

<sup>a,b,c,d,e</sup>Means within a row or interaction subclass with different superscripts differ ( $P < 0.05$ ).

<sup>1</sup>Means were corrected to a common fixed end of test weight of 123.2 kg.

<sup>2</sup>Individual pen (Building 1)/*Ad libitum*

<sup>3</sup>Individual pen (Building 1)/Restricted

<sup>4</sup>Individual pen (Building 2)/*Ad libitum*

<sup>5</sup>Individual pen (Building 2)/Restricted

<sup>6</sup>Standard group pen (Building 2)/*Ad libitum*

**Table 4.** Effect of rearing environment on growth performance to a fixed weight (122.5 kg).

| Treatment                                 | Rearing Environment |                    |                    |                    |                     | SEM   | P-value |
|---|---------------------|--------------------|--------------------|--------------------|---------------------|-------|---------|
| Item                                      | (1) <sup>2</sup>    | (2) <sup>3</sup>   | (3) <sup>4</sup>   | (4) <sup>5</sup>   | (5) <sup>6</sup>    |       |         |
| Number of pens                            | 32                  | 32                 | 8                  | 8                  | 16                  |       |         |
| <b><u>Growth performance</u></b>          |                     |                    |                    |                    |                     |       |         |
| Body weight, kg:                          |                     |                    |                    |                    |                     |       |         |
| Start of test                             | 38.4                | 38.4               | 38.3               | 38.3               | 38.4                | 0.77  | 1.00    |
| End of test                               | 124.8 <sup>ab</sup> | 121.7 <sup>c</sup> | 126.3 <sup>a</sup> | 120.7 <sup>c</sup> | 122.9 <sup>bc</sup> | 0.81  | <0.001  |
| Coefficient of variation (within-pen), %: |                     |                    |                    |                    |                     |       |         |
| Start of test                             | -                   | -                  | -                  | -                  | 11.4                | 0.79  | -       |
| End of test                               | -                   | -                  | -                  | -                  | 6.7                 | 0.4   | -       |
| Days on test <sup>1</sup>                 | 83.6 <sup>c</sup>   | 95.0 <sup>b</sup>  | 83.9 <sup>c</sup>  | 98.7 <sup>a</sup>  | 84.3 <sup>c</sup>   | 1.51  | <0.001  |
| Overall growth performance: <sup>1</sup>  |                     |                    |                    |                    |                     |       |         |
| Average daily live weight gain, g         | 1020 <sup>a</sup>   | 898 <sup>b</sup>   | 1020 <sup>a</sup>  | 862 <sup>b</sup>   | 1011 <sup>a</sup>   | 18.1  | <0.001  |
| Average daily feed intake, kg             | 2.79 <sup>b</sup>   | 2.34 <sup>c</sup>  | 2.91 <sup>a</sup>  | 2.35 <sup>c</sup>  | 2.85 <sup>ab</sup>  | 0.046 | <0.001  |
| Gain:feed, kg:kg                          | 0.365 <sup>b</sup>  | 0.382 <sup>a</sup> | 0.351 <sup>b</sup> | 0.367 <sup>b</sup> | 0.355 <sup>b</sup>  | 0.005 | <0.001  |

<sup>a,b,c,d,e</sup>Means within a row or interaction subclass with different superscripts differ ( $P < 0.05$ ).

<sup>1</sup>Means were corrected to a common fixed end of test weight of 123.2 kg.

<sup>2</sup>Individual pen (Building 1)/*Ad libitum*

<sup>3</sup>Individual pen (Building 1)/Restricted

<sup>4</sup>Individual pen (Building 2)/*Ad libitum*

<sup>5</sup>Individual pen (Building 2)/Restricted

<sup>6</sup>Standard group pen (Building 2)/*Ad libitum*



**Table 5.** Effect of rearing environment on growth performance over a fixed time and carcass characteristics at harvest.

| Treatment  | Rearing Environment |                    |                    |                    |                    | SEM    | P-value |
|--|---------------------|--------------------|--------------------|--------------------|--------------------|--------|---------|
| Item   | (1) <sup>3</sup>    | (2) <sup>4</sup>   | (3) <sup>5</sup>   | (4) <sup>6</sup>   | (5) <sup>7</sup>   |        |         |
| Number of pens                                       | 32                  | 32                 | 8                  | 8                  | 16                 |        |         |
| <b><u>Growth Performance</u></b>                     |                     |                    |                    |                    |                    |        |         |
| Body weight, kg:                                     |                     |                    |                    |                    |                    |        |         |
| Start of test  | 38.4                | 38.4               | 38.3               | 38.3               | 38.4               | 0.77   | 1.00    |
| End of test  | 137.1 <sup>a</sup>  | 123.7 <sup>b</sup> | 138.5 <sup>a</sup> | 119.3 <sup>c</sup> | 134.2 <sup>a</sup> | 1.61   | <0.001  |
| Coefficient of variation (within-pen), %:            |                     |                    |                    |                    |                    |        |         |
| Start of test  | -                   | -                  | -                  | -                  | 11.4               | 0.79   | -       |
| End of test  | -                   | -                  | -                  | -                  | 6.6                | 0.47   | -       |
| Days on test   | 97                  | 97                 | 97                 | 97                 | 97                 | -      | -       |
| Overall growth performance                           |                     |                    |                    |                    |                    |        |         |
| Average daily live weight gain, g                    | 1016 <sup>a</sup>   | 880 <sup>b</sup>   | 1034 <sup>a</sup>  | 839 <sup>b</sup>   | 993 <sup>a</sup>   | 22.2   | <0.001  |
| Average daily feed intake, kg                        | 2.88 <sup>b</sup>   | 2.33 <sup>c</sup>  | 3.04 <sup>a</sup>  | 2.33 <sup>c</sup>  | 2.89 <sup>b</sup>  | 0.051  | <0.001  |
| Gain:feed, kg:kg                                     | 0.353 <sup>bc</sup> | 0.377 <sup>a</sup> | 0.341 <sup>c</sup> | 0.359 <sup>b</sup> | 0.343 <sup>c</sup> | 0.0044 | <0.001  |
| Morbidity and mortality, %                           | 3.13                | 3.13               | 0.00               | 0.00               | 0.78               | -      | 0.75    |
| <b><u>Carcass characteristics</u></b> <sup>1,2</sup> |                     |                    |                    |                    |                    |        |         |
| Harvest live weight, kg                              | 138.2 <sup>ab</sup> | 125.4 <sup>c</sup> | 142.2 <sup>a</sup> | 122 <sup>c</sup>   | 135.6 <sup>b</sup> | 1.57   | <0.001  |
| Hot carcass weight, kg                               | 104.6 <sup>b</sup>  | 93.8 <sup>c</sup>  | 108.6 <sup>a</sup> | 91.2 <sup>c</sup>  | 103.7 <sup>b</sup> | 1.15   | <0.001  |
| Carcass yield, %                                     | 75.7 <sup>b</sup>   | 74.9 <sup>c</sup>  | 76.2 <sup>ab</sup> | 74.8 <sup>c</sup>  | 76.5 <sup>a</sup>  | 0.37   | <0.001  |
| Fat-O-Meater measurements (10 <sup>th</sup> rib):    |                     |                    |                    |                    |                    |        |         |
| <i>Longissimus</i> muscle depth, cm                  | 6.15                | 6.02               | 6.1                | 5.84               | 6.2                | 0.145  | 0.40    |
| Backfat depth, cm                                    | 2.54 <sup>b</sup>   | 2.11 <sup>c</sup>  | 2.95 <sup>a</sup>  | 2.03 <sup>c</sup>  | 2.64 <sup>ab</sup> | 0.094  | <0.001  |
| Predicted carcass lean content, %                    | 50.5 <sup>b</sup>   | 52.1 <sup>a</sup>  | 49.0 <sup>c</sup>  | 52.2 <sup>a</sup>  | 50.2 <sup>bc</sup> | 0.41   | <0.001  |

<sup>a,b,c,d,e</sup>Means within a row or interaction subclass with different superscripts differ ( $P < 0.05$ ).

<sup>1</sup>Means were not corrected to a common harvest live weight.

<sup>2</sup>Measured on all pigs that completed the growth study.

<sup>3</sup>Individual pen (Building 1)/*Ad libitum*

<sup>4</sup>Individual pen (Building 1)/Restricted

<sup>5</sup>Individual pen (Building 2)/*Ad libitum*

<sup>6</sup>Individual pen (Building 2)/Restricted

<sup>7</sup>Standard group pen (Building 2)/*Ad libitum*